SCIENCE FOR CULTURE[1]

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If there is anything the matter with science-teaching, one may be very hopeful that the difficulty will be cured when he considers the number of associations and clubs of science teachers formed to discuss plans for improving present conditions.

My subject needs a little definition.

Probably everyone who is teaching science is attempting to cultivate something. One aims at accuracy, skill, honesty of thought, discipline; another aims to cultivate imagination, power of generalizing, information, etc.

I have no disagreement with either party, except that they ought not to exist as parties. They should combine. The different departments of education should work toward one end. Certainly it cannot be the duty of one department to tear down what another constructs.

It is my purpose to speak of culture as we generally use the term when we speak of culture courses, liberal education, etc.

No one needs imagination more than the investigator, and no one has a better opportunity to cultivate it than the teacher of physics. The scientist and the humanist have not conflicting duties—indeed, there is no occasion to make a distinction between them. Humanism which is not scientific and science which is not humanistic are worthless.

Professor Cooke says: "Science culture differs in its methods from the old classical culture, but it has the same spirit and the same object."[2]

Professor Burr, speaking of the fundamental idea of the humanists, says:

[1] Paper read at the annual meeting of the Central Association of Science and Mathematics Teachers, University of Chicago, November 30, 1906.

[2] J. P. Cooke, *Science Culture*, p. 20.

It was their open purpose in which they gloried to treat of things as they actually existed, to get as near to the life of the community as the best knowledge would bring them; in other words, to touch human life intimately and at the greatest possible number of points.[3]

Let it be conceded that it is very desirable to cultivate accuracy, self-dependence, mental honesty, etc. There is no short-cut, no royal road, to these results. Such fruits do not come out of forty laboratory exercises. They are a slow growth of many years. Quantitative work simplified, made direct, and put in its proper sequence with qualitative work, may profitably occupy, say, one quarter of the effort of a high-school pupil in physics. But science is something more than measurement. To be sure, when men began to measure, they took great strides forward; but it is equally true that research comes to a standstill when information and imagination are wanting. The chief difficulty with science-teaching today, both in the high school and in the college, is that we do not give sufficient information.

Culture courses, or information courses, are often spoken of scornfully as a "smattering of all the 'ologies."

We have the mistaken idea that we can cut a clean swath in education; can teach a subject thoroughly; can treat a few principles and teach the whole truth about them first hand. But this is to attempt the impossible. Neither the immature nor the mature human mind works that way.

Dr. Simon Newcomb says:

The plausible system of learning one thing thoroughly before proceeding to another, and taking things up in their logical order only, should be abandoned. Let us train the pupil as rapidly as possible in the higher forms of thought and not be afraid of his having a little smattering of advanced subjects before they are reached in regular course. Let us remember that thoroughness of understanding is a slow growth, in which unconscious cerebration plays an important part, and leaves it to be slowly acquired. A teacher aiming at thoroughness might have kept Cayley or Sylvester working half his life on problems of advanced arithmetic without reaching his standard of thoroughness."[4]

[3] W. H. Burr, *Science*, October 26, 1906.

[4] Simon Newcomb, *Educational Review*, April, 1906.

The teachers of De Morgan, the mathematician, found him dull in mathematics.

Let me recall the scene from that charming little book, *Philip's Experiments,* where Philip and his father are surveying in the field when the schoolmaster is introduced.

Philip's schoolmaster pointed out that, after he had a systematic training in geometry and trigonometry, he would have little difficulty with the problems which arise in surveying. He also said that the plane table should have a telescope instead of rude sights, and he described various accurate instruments, and intimated that I was cultivating habits of inaccuracy in Philip. Training in science which was not highly accurate he believed was worse than no training at all. I listened, but I remembered that this teacher had kept Philip at work making highly accurate measurements with a delicate balance. The boy had not appreciated the construction of the balance, for he had never made weighings with a rough instrument, and his mind had been kept so fixed upon the third place of decimals that he did not appreciate what specific gravity really means. I could see that the schoolmaster in his endeavor to refine had forgotten the difficulties of an immature mind. Philip was on one contour line and he on another, and it would take more than a megaphone to put them into communication.[5]

In obtaining quantitative work, exactness must be demanded; but exactness is a quality that comes relatively late in youthful minds as in that of the race. We are attempting to force nature; we are anticipating maturity of mind when we crowd into a curriculum subjects in advance of the time when the mind of the average boy or girl is able satisfactorily to pursue these subjects. . . . . Probably the fault is not with the subject physics, but with the method. Too much quantitative work is demanded of both boys and girls; too little attention is given to the great names who have developed the subject and made inventions household words.[6]

We are too much afraid of teaching some things which have to be modified or even unlearned later. "Unlearning" is quite as educational as learning, and does no harm to a reasonable being; indeed, it may be a cure for bigotry. It is more important to cultivate open-mindedness than it is to be correct.

Professor Hopkins, in giving a simple, provisional definition of an acid, says:

At that stage of instruction this simple working definition is sufficient. More would be an enormity. What though the definition be untrue? The

[5] John Trowbridge, *Philip's Experiments,* p. 79.

[6] William L. Felter, *Educational Review,* April, 1906.

instruction, it is to be remembered, demands simplicity and progression—not truth. . . . . It shows the subject presented, not as a carefully completed, rounded and exact definition . . . . but as a part-truth at first which grows with his capacity for understanding.[7]

We are too sensitive about being up to date with our facts and theories. Since it has become impossible for any man to keep up with the literature of more than one subject, men have become timid about teaching more than one subject. But it is not difficult to show that the man who keeps himself moderately well informed upon the progress in several sciences is better prepared to teach than the one who knows only one subject. The weakest thing about research today is that our men are not *widely* informed.

One who has traveled much and become familiar with types of country may find his way through an unknown territory and readily suspect it when he is approaching a spot sought for. The ant studying his grains of sand does not get this view of a country. It is the "bird's-eye" view. Sailors by extended experience become accurate observers of weather phenomena. Miners and farmers and horse-dealers and experts of all kinds acquire their accuracy of knowledge chiefly by the extensive method.

Professor Trowbridge says: "The natural progress of our study of any subject is from the qualitative, or the comparatively rough evidence of our senses, to the quantitative."[8] He says we need the countryman's habit of "hefting" a thing before weighing it.

Teachers in languages are everywhere insisting upon the advantages of reading at sight and reading widely. Why should teachers of science be slow to learn the science of teaching?

We talk about trying to rid ourselves of preconceived notions; but preconceived notions are quite necessary to progress, and the ability to preconceive notions is absolutely essential to research. It is no argument against a gift that it is capable of perversion. We want to be put in control of our faculties, not deprived of them by education.

[7] Arthur John Hopkins, *School Science*, April, 1904.

[8] John Trowbridge, *New Physics*, Preface.

We have reversed the natural order and tried to train high-school pupils in induction. Using the forms of induction in the high school may be a species of dishonesty. After all, the pupils learn not from the experiment, but from the teacher or the text-book. We teach them to test carbon dioxide gas with lime water, but we have to inform them that nothing else will turn lime water milky, and so it is only a roundabout way of telling them the whole story. We have great satisfaction in calling this the heuristic method, and we make the children prigs by leading them to think that they are acquiring knowledge first-hand.

The self-activity that high-school pupils need is that which they may get in the laboratory by doing experiments merely for the purpose of coming in contact with things, making their knowledge real, acquiring "a certain balance of judgment which comes from actual contact with things."

"The mind must rest upon physical laws for a comparatively long period in order to understand their true significance."

Pupils learn by imitation chiefly. Professor Trowbridge[9] recommends performing in lectures the experiments which the students afterward perform themselves in the laboratory.

In many schools throughout this country one may find eminently successful teachers of physiography who proudly acknowledge that they learned *by imitation* of Professor William M. Davis both their subject and their method of teaching. I should characterize Professor Davis' method as an exceedingly skilful way of *giving the information* which his students could not acquire first-hand in a thousand years, and his method is equally successful in preparing students for research or for teaching.

The teaching of science should accomplish the greatest possible good to the greatest possible number. The time was when education proceeded without much reference to the public. It was intended for the select few. A rapid change is in progress. Within recent years the public high schools have become the most important educational institutions in the country. They surpass the colleges in buildings, laboratory equipment, and

[9] *New Physics,* Preface.

teaching force—not only in quantity, but in quality. In the rapid growth of colleges, the available funds have not increased in proportion to the increase in number of students. The result is that the classes have been assigned inferior instructors.

The growth of research, by diverting funds and diverting men, has caused college teaching to deteriorate.

The general testimony of students is that they work much harder in the high school than in the college. Who knows how it might affect the intellectual and moral character of college students to have courses of instruction which were capable of absorbing their chief interest, so that they would not feel ashamed to say they were more interested in their studies than in their diversions?

Theoretically the pursuit of research ought to enrich one's teaching, but in actual practice attention to the art of teaching wanes as attention to research increases. The first requisite of a teacher is to be actuated by a desire—a fervent desire—to instruct others. If one can work at research and not have that ardor dampened, it is well. But to hold a teacher's position and to scorn the work of teaching is simply dishonest; and even though one's researches may be more valuable to the world than his instruction, those who have paid tuition for instruction have a just claim against him. Probably most of the money received from tuition fees and from endowment by undergraduate colleges was given for purposes of instruction; but, after diverting much of this to the support of research, and after giving the students very indifferent instruction, we tell them that their tuition fees do not cover the cost of their education.

These college students have a starvation course in measurements called physics. Their tutors, having just passed through the same course with excessive specialization, are suspicious of that expansive thing called culture. They affect to despise, not only the public, but all departments of learning other than their own. They surpass the theologians in narrowing down their lines of orthodoxy. Some teachers of science are like polarizers. The truth which gleams in all directions is narrowed down to one plane when it is transmitted by them. Their standards

would unclass Davy, Faraday, Tyndall, Pasteur, Humboldt, Maxwell, Huxley, Agassiz, Cooke, Shaler, and the like; for these men all preached the doctrine that science is good for culture and should be given to all. Those who interpret science as cold-blooded and exclusive have, not only nine-tenths of mankind against them, but a majority of the men of science, and particularly the leaders of all time.

Davy was a poet, and his high literary abilities made him a great teacher and likewise aided profoundly his researches. All of the men mentioned above were natural philosophers, with all the diversity of interests which that title indicates. All were humanists, and many of them devoutly religious.

The influence of the college in all departments, classical as well as scientific, is toward driving culture, in the sense in which I am using it, out of the schools; first, by narrowing the education which it gives to those who go out to teach in the schools, and, second, by prescribing a syllabus for the schools narrowly interpreted by examiners and bigotedly enforced by readers of examination papers. The schools cannot even give a cultural course in music. The brevity of life makes it necessary to have everything count toward entrance into college, and the college accepts only musical mathematics. There is not a department which is not handicapped in this way. It is impossible to teach anything as a culture when it is necessary to prepare for examination—particularly an examination set by another person. No one can justly estimate the progress and the proficiency of a class except one who has been with them throughout their study. If a supervisor's examination is thought to be necessary, let the teacher prepare the questions, and submit both questions and answers to the supervisor. For a "reader" in four minutes to pass upon a year's work of a student wholly unknown to him is an absurdity.

I cannot look upon a syllabus as a blessing, even though it may be prepared by a majority of the teachers. Why should uniformity be thought necessary or desirable? The "New Movement among Physics Teachers" is very helpful so long as it keeps in a state of solution, but we may regret its crystallization.

One may hope that, if we must have a syllabus, it may be extensive enough to include all that may be desired by any considerable number of teachers, and that each teacher shall be allowed great freedom of choice within the syllabus.

The high schools are coming nearer in touch with the public mind every day. They are powerfully influencing public sentiment, and are in turn being profoundly influenced by public sentiment. We have lately had evidence that science was in the ascendency in the minds of the people, by their vast gifts for equipping schools and colleges for teaching science; but, unless our teaching is adapted to the needs of the majority, we shall soon see the funds drifting in other directions, or, what is more likely, we shall see ourselves drifted away from our moorings by the resistless tide.

In the ultimate analysis the same public supports the colleges and the schools. The college looks to the public for its funds, whether they be legacies or legislative grants or tuition receipts; it looks to the public for exemption from taxation; it looks to the public for the patronage of its sons and daughters. The public in turn demands of the college better service in the matter of giving instruction.

People have recently learned that they must square their lives according to physical principles, and they and their children have turned to educational institutions for information with an eagerness that is irresistible.

Their children have increased the attendance upon the colleges fivefold in recent years, and they themselves have entered university-extension courses in countless thousands. In some cases the extension courses furnish quite as good instruction as any given at the university. Faraday was started on his course as a scientist by Davy's public lectures; and Cooke says[10] that he got his first taste of real knowledge from the lectures at the Lowell Institute, although he was a pupil in the Boston Latin School at the time—and that taste awakened an appetite which was never satisfied. Cooke says he eagerly sought the popular science of the day, which was vastly inferior to what we have

[10] J. P. Cooke, *Scientific Culture and Other Essays*, p. 72.

today. We may now rank a few of the daily newspapers among our better teachers of science. Huxley said: "Science is not solely for the men of science, but for the people."

General courses in college should be culture courses. They should be what their name indicates—general surveys. A majority of the students in such courses will not and ought not to pursue the subject longer than one year, when we come to balance up the claims of all the subjects in a liberal course. Why then do the instructors persist in giving them that which is absolutely meaningless, unless it be joined to a protracted study of one subject for several years; and why do they give them that which properly belongs not so much at the beginning as at the end of the course in that particular subject? Such general-survey courses are quite as important to those who will go on to specialize in the subject as to the students who will pursue it no further. Large knowledge acquired by general surveys in many fields is necessary before one can select and organize. During his career in high school and undergraduate college a student should be encouraged to take general cultural courses in each and all the sciences, whether his aim is to specialize or not.

The time has already come when to know any one of the sciences thoroughly it is necessary to know the rest; in fact, all the so-called natural sciences are different branches of one great science.[11]

It is not possible to get an elementary knowledge of any one science except by this process of browsing among many.

We have a duty to our children which we cannot avoid, if we would, and for which we shall be held responsible by our posterity. These children are entering life surrounded not only by all the wonders and glories of nature, but also by giant conditions, which, whether stationed on their path as a blessing or a curse, will inevitably strike if their behests are not obeyed. So far as science has been able to define these giant forms it is our duty, as it is our privilege, to point out to those we are bound to protect and guide; and in many cases it is in our power to change the curse into a blessing, and to transform the destructive demon into a guardian angel. After that command of language which the necessities of civilized life imperatively require, there is no acquisition which we can give our children that will exert so important an influence on their material welfare as a knowledge of the laws

[11] Elisha Gray, *Nature's Miracles*, p. 170.

of nature, under which they must live and to which they must conform; and throughout whose universal dominion the only question is whether men shall grovel as ignorant slaves or shall rule as intelligent servants.

It is perfectly possible for a child before fifteen years of age to acquire a real and living knowledge of the fundamental facts of nature on which physical science is based. This is not a question of natural endowment or special aptitude.

To arouse a love of study in any subject is to take the first step toward making your man a scholar (I want to emphasize scholar), while to fail to gain his interest in any study is to lose the whole end of education.[12]

We greatly wrong a pupil if we leave him unfitted to enter into the great inheritance of scientific truth obtained by past and present research. In striving to work out this problem let us, first, inculcate a habit of scientific thinking; second, give as wide a knowledge as possible, and third, awaken an interest which shall be lasting.[13]

Mr. Roy Fryer says:

That course is best which contributes most to general information and culture by acquainting the pupil with a wide range of chemical facts, while at the same time it trains his powers of observation and of reasoning from those observations.[14]

We make a great mistake when we shape our courses so as to eliminate all except those who are mathematically inclined and ready for specialization.

No educated man can expect to realize his best possibilities of usefulness without a practical knowledge of the methods of experimental science. . . . . It is not to be expected or desired that many of our students should become professional men of science . . . . [yet] any system of education is radically defective which does not comprise a sufficient training in the methods of experimental science to make the mass of our educated men familiar with this tool of modern civilization.

The elementary principles and the more conspicuous facts of chemistry are so intimately associated with the experiences of everday life, and find such important applications in the useful arts, that no man at the present day can be regarded as educated who is ignorant of them. . . . . Physical science has become a great power in the world. Indeed, after religion, it is the greatest power of our modern civilization. Consider how much it has accomplished during the last century toward increasing the comforts and enlarging the intellectual vision of mankind. . . . . It is frequently said,

[12] J. P. Cooke, *op. cit.*, p. 81.

[13] J. H. Denbigh, *School Science*, October, 1906, p. 635.

[14] Roy Fryer, *School Science*, December, 1906.

in defense of the exclusive study of the records of ancient learning, that they are the product of thinking, loving, and hating men like ourselves, and it is claimed that the study of science can never rise to the same nobility because it deals only with lifeless matter. But this is a mere play on words, a repetition of the error of the old schoolmen. Physical science is noble because it does deal with thought, and with the very noblest of all thought. . . . . The ancient logic never relieved a moment of pain, or lifted an ounce of the burden of human misery. The modern logic has made a very large share of material comfort the common heritage of all civilized men.[15]

Teachers in their zeal for maintaining their standards often lose their missionary spirit, and act as though they would exclude the large majority of students from the department of knowledge over which they preside. Their love for a particular science has overshadowed their love for their fellow-men. Such are not true representatives of the men of science.

No teaching is of any real value that does not come directly from the intelligence and heart of the teacher, and thus appeal to the intelligence and heart of the pupil. . . . . There is no nobler service than the life of a true teacher; but the mere taskmaster has no right to the teacher's name and can never attain the teacher's reward.

Value scientific studies not simply because they cultivate the perception and reasoning faculties, but also because they fill the mind with lofty ideals, elevated conceptions, and noble thoughts. Indeed, I claim that there is no better school in which to train the aesthetic faculties of the mind, the tastes, and the imagination than the study of natural science.[16]

The history of science tells of a "multitude who have worked in faith for the love of knowledge" and "made themselves and their fellows more noble men."

[15] J. P. Cooke, *op cit.*

[16] *Ibid.*